REPORT RESUMES

ED 016 391 24 EM 005 645

THE EVALUATION OF ELECTRONIC SELF-INSTRUCTION ON PIANO KEYBOARD. FINAL REPORT.

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REPORT NUMBER CRP-3265 PUB DATE AUG 66
REPORT NUMBER R-57
REPORT NUMBER BR-5-0259
GRANT OEG-6-10-038
EDRS PRICE MF-$0.25 HC-$2.24 54P.

DESCRIPTORS- *ELECTROMECHANICAL AIDS, *MECHANICAL SKILLS, *FEEDBACK, *MUSIC TECHNIQUES, *TEACHER EDUCATION, PROGRAMED TUTORING, RATING SCALES, ANALYSIS OF VARIANCE, ATTITUDES

OBJECTIVES OF THIS STUDY WERE TO COMPARE THE LEARNING OF PIANO KEYBOARD SKILLS BY CONVENTIONAL INSTRUCTION AND BY AN "ELECTRONIC KEYBOARD TUTOR" (EKT) DEVICE, BOTH PROVIDING MONITORING, AND IMMEDIATE FEEDBACK. THE EKT PROVIDES VISUAL FEEDBACK ONLY--IT IS A SYSTEM OF ELECTRIC SWITCHES CONNECTED TO A PIANO KEYBOARD. EDUCATION STUDENTS INITIALLY AT THREE LEVELS OF PIANO PROFICIENCY IN A MUSIC FUNDAMENTALS COURSE WERE ASSIGNED BY CLASS TO THE INSTRUCTIONAL MODES. MULTIPLE MEASURES OF PROFICIENCY INCLUDED PERFORMANCE RATINGS BY THREE JUDGES, AND AMOUNT OF PRACTICE TIME REQUIRED TO REACH A CRITERION PERFORMANCE LEVEL. ANALYSIS OF VARIANCE SHOWED THAT FOR INITIALLY PROFICIENT STUDENTS, EITHER INSTRUCTIONAL METHOD IS ADEQUATE, BUT FOR NAIVE STUDENTS, THE CONVENTIONAL METHOD IS SUPERIOR. ALSO, PRACTICE TIME WAS SIGNIFICANTLY DIFFERENT BETWEEN THE TWO INSTRUCTIONAL METHODS. STUDENT ATTITUDES TOWARD THE EKT WERE NEUTRAL, AND INSTRUCTOR ATTITUDES VARIED. RELUCTANCE TO PRACTICE ON THE EKT IS DISCUSSED. (LH)

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Final Report

Cooperative Research Project #3265

Office of Education

U. S. Department of Health, Education and Welfare

teaching research

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R-57

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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FINAL REPORT

Project No. 3265

Grant No. OE6-10-038

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August 1966

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education
Bureau of Research

EM 005 645

The Evaluation of Electronic Self-Instruction on Piano Keyboard

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Victor E. Lund

August, 1966

The research reported herein was performed pursuant to a grant with the Office of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

TEACHING RESEARCH DIVISION

Oregon State System of Higher Education

Monmouth, Oregon

ACKNOWLEDGEMENTS

Dr. Leonard W. Rice, President, Oregon College of Education, for his interest in and support of this project.

Dr. Edgar H. Smith, Chairman, Music Department, Oregon College of Education, for his interest and administrative cooperation.

Mrs. Miriam Bednarz, Mrs. Alice Glasgow, Dr. Robert B. Glasgow, and the late Mrs. Denise Redden, Music Department staff members, Oregon College of Education, for their cooperative participation in this project.

Mr. Casper F. Paulson, Assistant Research Professor, Teaching Research Division, Oregon State System of Higher Education, for his faith in me and continuous support throughout this project.

The "project team" and its accompanying spirit, which made such an undertaking possible. The members were Timothy J. Pettibone, Electronics Technician, Teaching Research Division, whose responsibility was the actual design of the circuitry to accommodate the features desired; Allen J. Fulmer, Computer Systems Engineer, SPEDTAC, who furnished valuable counsel of theoretical application, and Dr. David Wallace, Associate Professor of Music, Oregon College of Education, who supplied the ingredients of subject matter from which the design of circuitry evolved.

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Introduction

In American education the expectation is virtually universal that the adequately trained elementary school teacher will have at least some minimum proficiency in keyboard (piano and organ) instrument skills. Music education, particularly in the primary and intermediate grades, is usually closely integrated in the instructional program, and classroom teachers are expected to be relatively self-sufficient in supplying music experiences for their students. Consequently, certification requirements and degree programs for elementary teachers commonly require either specific training or demonstration of proficiency in keyboard instrument skills.

The music skills required of elementary teachers are typically developed in a music fundamentals course. While the content of these courses may vary, commonly students are expected to develop familiarity with fundamental music styles, application of music techniques to other curricular areas, familiarity with musical games appropriate for various grade levels, instructional techniques to be employed in developing musical skill of elementary school children and basic competency with piano and organ keyboards.

Elementary music series books and classroom music courses in teacher training institutions place considerable emphasis on student acquisition of basic keyboard skills. In particular, there is the aforementioned assumption that when the student completes these courses he will be able to use the piano in the elementary classroom as an accompanying instrument for classroom singing activities. The elementary series books provide full piano accompaniments for those with the skill to use them. Chord symbols are provided for those with lesser skills.

Teaching keyboard application of key signature recognition and of keyboard patterns to be utilized in the classroom activity by the elementary teacher requires a considerable amount of class time in music fundamentals courses. This application is usually taught in the following manner: (1) the scale patterns and chord progressions in a certain key are explained and demonstrated to each student in turn, (2) the student is then directed to practice this skill outside of class and (3) the student demonstrates his acquired keyboard skill to the instructor, who checks the correctness of his performance. The degree of correctness and facility is viewed as evidence of practice by the student. An incorrect performance would indicate the need of additional practice. This checking phase is necessarily a recurrent operation throughout the term for each student and when this operation is multiplied by the number of students enrolled in class, a problem is immediately apparent. There is insufficient time to do an adequate job of instruction in both course content and in keyboard skills. Adequate instruction in one must be done at the expense of the other.

The continuous and increasing demands for well-trained elementary school teachers and the increasing number of students choosing this profession call for increasing class size and pupil-teacher ratios in music fundamentals courses. Yet, the nature of the classes with their required pupil performances call for small class size and pupil-teacher ratios.

In addition, considerable specialized training and ability are expected of a college music instructor, but teaching fundamental keyboard skills to naive students requires that he spend much time listening to their performances and evaluating their progress. The time and effort devoted to this rudimentary and repetitious instruction is similar to that given to a young child in private instruction. This instructional method is looked upon by most college instructors as a necessary evil, which must be endured. It is unfortunate that a highly-trained instructor is unable to make better use of his musical ability. It is obvious that the feedback-giving role of the instructor in such settings is a highly inefficient use of his time.

Another problem is that which confronts the student. The elementary education teacher candidate typically has had little or no previous musical training. This may create emotional overtones which inhibit the total learning process for such students. As with dancing, swimming, and many other skills which must be demonstrated in public the most acceptable time for learning has passed and public demonstration of ineptitude is humiliating. Yet the nature of the learning task requires some active performance, however inept, from him, so that he might be given feedback regarding the quality of his performance. Private tutoring for all students is simply not feasible. On the other hand, practice without feedback is ineffective. When performance and feedback take place in a class setting, the feedback is not merely informative but often threatening to the student. In a class where the naive student is the exception, this threat may approach dramatic proportions.

Review of Related Research

Various studies of knowledge of performance (McPherson, Dees and Grindley, 1948; Michael and Maccoby, 1953; Ammons, 1956) have shown that students improve in their performance when they are given knowledge of results. Michael and Maccoby (1956) concluded that "the most important factor in influencing the amount of learning in this experiment was the provision of knowledge of correct response (KCR)." Wolfle (1951, p. 1267) stated that "laboratory studies are unequivocal in emphasizing the importance of giving a subject as specific and as immediate information as possible concerning the outcome of his efforts."

Skinner (1954) suggested that laboratory research on behavior had a direct bearing on the teaching process. He felt that application of research findings could be effectively brought about by using a mechanical device. This device was to supply the student immediately with knowledge of his correct response. In 1961 Skinner stated that "exploratory research in schools and colleges indicates that what is now taught by teacher, textbook, lecture or film can be taught in half the time with half the effort by machine."

The reports of several recent studies (Barnes, 1964; Buchanan, 1964; Carlsen, 1964; Woelflin, 1964) point to the desperate problem faced by music educators in colleges which train elementary teachers. Plainly stated, the regular classroom teachers are not trained adequately to do an effective job of teaching music. Buchanan (1964) stated:

> "The ability to play a piano is an asset to a regular classroom teacher, and often times it is the determining factor in being selected for the job ....Something must and can be done to compensate this ...(training)... deficiency. Just as in science, mathematics, languages and other areas of learning, music education must streamline and revise its methods and procedures of instruction. Certainly this is true of piano teaching. The purpose of such a revision is to more effectively and more economically, from the standpoint of time, prepare the prospective teacher to meet his pianistic needs."

Carlsen (1964) used programed instruction to develop melodic dictation ability and concluded, "The results of the experiment clearly indicated the value of the (method)... The potential of programed instruction appears great ... to release the teacher for tasks which only the teacher can do." Woelflin (1964) experimented with instrument instruction (clarinet) by program to free the teacher from tasks which amount to supplying feedback. He found that students who received machine instruction performed as well as those who were personally tutored. Barnes (1964) used an instructional program to teach factual information in music and found that the program not only "could save many hours of instructor time and student time, but the use of the programed book could permit the teacher at the outset of the course to assume a specific level of competence on the part of every student in the class."

A call for help in the matter of research itself was issued by Petzold (1964) at the Music Educators National Conference, 1963. He commented that "during the period 1952-62, 70% of the music education dissertations listed in Dissertation

Abstracts were the relatively uncomplicated and highly popular survey studies and 30% were basic or action type. Often the survey was made in desperation and did nothing but help perpetuate the commonplace in music education research." He stressed the need of professional team work, i.e. "the teacher must: (1) be relieved of a portion of his teaching load in order to have sufficient time to carry on investigative activities designed to improve the program; (2) be given assistance in planning projects, and consultative services by trained researchers should be available throughout the course of the projects. Such cooperation ... will ... result in substantial gains toward improvement of programs and instructional procedures."

Method

This study compared two instructional modes for teaching selected piano keyboard skills, a Teacher Mode and an Electronic Keyboard Tutor Mode. Both instructional modes utilized tutorial techniques. The Teacher Mode employed an experienced college music professor to monitor student performance and provide visual and verbal feedback regarding the correctness of the performance.

The Electronic Keyboard Tutor (EKT) was specifically designed to accomplish the monitoring-feedback tasks described above, except that it was limited to visual feedback only. The EKT is actually a complex system of electric switches sequenced logically through relay systems to provide monitoring and feedback capabilities for selected scales and chord progressions. The EKT has the essential features of the logic system of a small fixed-program computer. It was, in fact, constructed from modular circuitry designed for computer systems. It is important for the reader to keep in mind that, although the EKT has features similar to those of computing machinery and is described in computer terms, it is not a computer, nor is it in any way connected to a computer.

The circuitry system of the EKT is attached through the back of a regular piano to the keys of the middle three and one-half octaves. Thus the total EKT consists of three components: (1) a circuitry system (Program Console), (2) a regular piano, and (3) a Feedback Panel. The EKT configuration is shown in Figure 1.

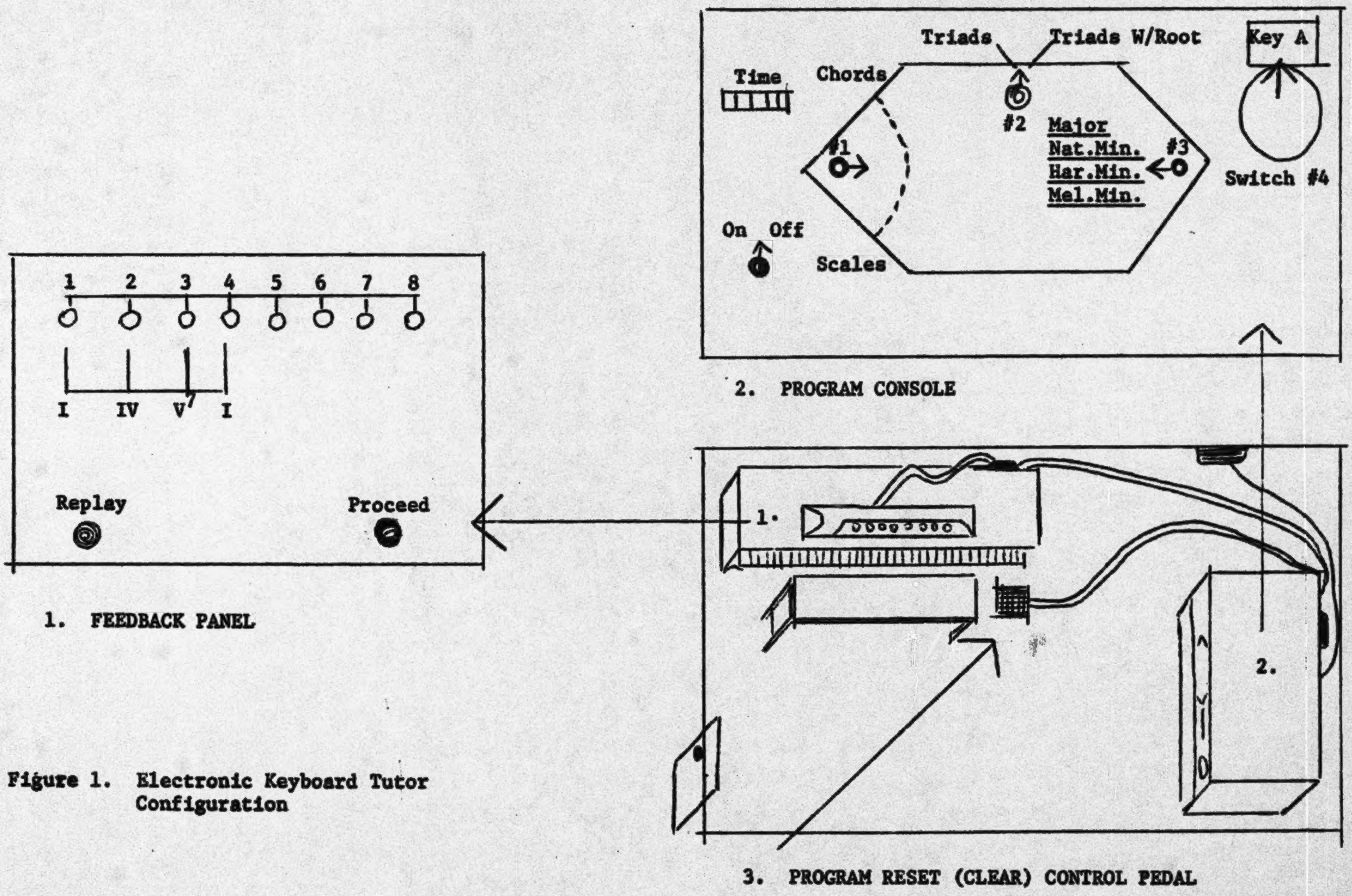
1 2 3 4 5 6 7 8
I IV V7 I
Replay
Proceed
1. FEEDBACK PANEL
Time
Chords
Triads
Triads W/Root
Key A
#1
#2
#3
Major
Nat.Min.
Har.Min.
Mel.Min.
Switch #4
On Off
Scales
2. PROGRAM CONSOLE
1.
2.
3. PROGRAM RESET (CLEAR) CONTROL PEDAL

Figure 1. Electronic Keyboard Tutor Configuration

Three regular practice pianos were equipped to accomodate the EKT Mode of instruction. These were so equipped that when a piano key is depressed, an electric circuit is closed which sends an impulse to the Program Console for evaluation. This resultant evaluation is then indicated in the form of a flashed light on a Feedback Panel located above the music rack on the piano. The evaluation is based on two consecutive questions. They are: (1) Is a note being played?, and (2) Is the note correct? A "Yes" answer to the first question is followed by evaluation and instant feedback is given to the student on the Feedback Panel. A "Yes" answer to the second question triggers a "Proceed" light and advances the tracking light to the next step of the scale. A "No" answer to the second question triggers a "Replay" light and the tracking light remains at the position of the error.

Students may change their practice from scales to chord progressions by turning the appropriate switch on the program console. In the case of Triads, the same evaluation procedure and feedback is indicated but the circuitry requires that three keys must be depressed at once. The feedback is silent (lights) and as patient as any teacher might be. In addition, the practice is private. If the student becomes confused during a sequence he can press a reset pedal with his foot. This clears the program of its memory to enable the student to start again at the first step.

To allow for students to operate the E.K.T. by themselves the device was constructed with durable circuitry which can withstand frequent and sometimes unintentional hard use. A complete schematic for the EKT is provided in Appendix A.

Objectives

This research sought to determine:

1) whether students using the Electronic Keyboard Tutor demonstrate at least as much proficiency in playing the selected scales and chord patterns as those taught in the described conventional manner,
2) whether students using the Electronic Keyboard Tutor require equal or less practice time to reach a pre-established criterion of performance than those taught in a conventional manner,
3) the attitudes of students who used the Electronic Keyboard Tutor toward that device,
4) if, after using the Electronic Keyboard Tutor, instructors indicate a preference for its continued use.

Sample

Subjects were students enrolled in Music Fundamentals classes at Oregon College of Education during the 1965-1966 school year. The Music Fundamentals sequence consists of two courses, the first of which is a prerequisite for the second. Five sections of the prerequisite course were offered during the year - three during the Fall Quarter, and one each during the Winter and Spring Quarters. These sections were assigned to one of the two instructional modes - three sections (63 subjects) to the Electronic Keyboard Tutor Mode, and two sections (39 subjects) to the conventional Teacher Mode.

During the first week of the class, students were interviewed to determine their previous experience with the piano. Three levels of piano proficiency were identified: Level I - those with no previous experience; Level II - those with no more than two years of piano training, all of which was obtained during the elementary school years; and Level III - those who had received sufficient training to be considered somewhat proficient. The numbers of subjects at each level for each instructional mode are shown in Table 1.

Table 1

Numbers of Subjects at the Three Proficiency Levels for Each Instructional Mode

	E.K.T. Mode	Teacher Mode	Total
Level I	42	27	69
Level II	9	5	14
Level III	12	7	19
Total	63	39	102

Instruction

At the beginning of the course, all subjects were informed that they would be expected to demonstrate, individually, their ability to play scales and four-step chord progressions in the keys of G, D, F, B^b, A, A^b, E, E^b and C with acceptable tempo and regularity, by the end of the academic quarter. Concurrent with piano training all subjects received instruction in the basic elements of musical notation, and in the theory of scales and chords.

The course was planned such that each instructor would demonstrate the scale and chord progression for one key each week. Subjects were instructed to practice the scale and chord progression for that key during that week of instruction. After approximately two weeks it was noted that subjects in the EKT Mode were not engaging in any practice. To ensure that EKT subjects would not delay practice to the point where there was insufficient time remaining in the quarter to permit all of them access to the three EKT's used, a more rigid practice schedule was established. This more rigid schedule also permitted maintenance of similarity in the two modes, thus avoiding contamination of the experiment by introduction of conditions of massed vs. distributed practice.

Under the modified instructional plan subjects in both modes were introduced to scales and chord progressions in four keys during a two-week period and in the five remaining keys during the succeeding two-week period. To ensure practice by EKT subjects, a "test" was administered over the keys covered at the end of each two-week period. Further, each subject in EKT Mode was assigned a specific practice time each day for his use.

Subjects in the groups using the Electronic Keyboard Tutor did not perform in class or receive feedback from the instructor. All practice and feedback was accomplished through use of the device. In the regular class meetings for these students, other areas of musicality, such as music literature, were presented.

The conventional group, during this same time, experienced an instructional method widely used throughout the country. This consisted of each student, in turn, performing scales and chord progressions, receiving feedback from the instructor regarding his accuracy, and witnessing the same process enacted with other students.

Data

Four types of data were collected during the study: practice time records, demonstrations of piano proficiency, attitudinal information, and course instructor reactions.

Practice time cards were distributed to all subjects in both instructional modes and also were placed on all school pianos. Teacher Mode subjects recorded all practice time, whether spent on school or home pianos or in performance in class. Total time spent by each student was determined. Practice time for EKT subjects was recorded mechanically on the EKT, which was then transferred to practice cards and returned to the instructors.

Piano proficiency was determined from instructor ratings of tape recorded demonstrations by each subject. The tape recordings were independently evaluated by three judges, all members of the music faculty who knew neither the identity nor the instructional mode of the subjects. The score assigned to each subject's performance was the average of the three ratings given by the evaluators.

This test required subjects to play all practiced scales and chord progressions in ascending and descending order. The evaluators then chose three scales and three chord progressions which were scored. The total score was a weighted sum of three subscores - accuracy, tempo, and regularity. The accuracy score was determined by counting the number of errors noted in the performance and subtracting this from the total possible number of correct responses, each note or chord being a response. Tempo and regularity scores were ratings between 1 and 5 given by the evaluator. Accuracy scores were weighted by a factor of 6, tempo scores by a factor of 2.5 and regularity scores by a factor of 1.5.

Since all scores were composites of the three judges' ratings, determination of interjudge reliability is not especially crucial. Interjudge reliability was, however, determined through intraclass correlational techniques (Winer, 1962). These intercorrelations were consistently high and are shown in Table 2.

Table 2

Intraclass Correlations for Scores Given by Three Judges to Random Samples of 31 EKT Mode Subjects and 25 Teacher Mode Subjects

Chords

	Accuracy	Tempo	Regularity
EKT Mode	.95	.73	.80
Teacher Mode	.89	.71	.81

Scales

	Ascending Accuracy	Descending Accuracy	Tempo	Regularity
EKT Mode	.96	.97	.82	.84
Teacher Mode	.95	.88	.97	.81

Results

Objective #1

"Will students using the Electronic Keyboard Tutor demonstrate as much proficiency in playing selected scales and chord progressions as those taught in the conventional manner?"

An analysis of variance (ANOVA) of proficiency scores was completed and is summarized in Table 3. The ANOVA was completed with main effects for proficiency level and instructional mode, both of which were fixed variables (Green and Tukey, 1960)

Table 3

Summary Data for ANOVA of Proficiency Scores for Instructional Modes and All Proficiency Levels

Source of Variation	d.f.	Sums of Squares	Mean Square	F
MODE	1	319.73	319.73	3.46
LEVEL	2	820.31	410.16	4.44*
MODE X LEVEL	2	1,232.57	616.29	6.68**
WITHIN	92	8,492.94	92.31	
TOTAL	97	10,865.55		

*p < .05
**p < .01

As would be anticipated, the ANOVA revealed a significant difference in demonstrated proficiency for subjects having various degrees of proficiency upon entering the study, i.e., those with greater entering proficiency demonstrated greater proficiency upon completion of training regardless of the training mode experienced. The analysis also revealed a significant interaction between entry level and instructional mode ($p < .01$). This interaction is shown graphically in Figure 2.

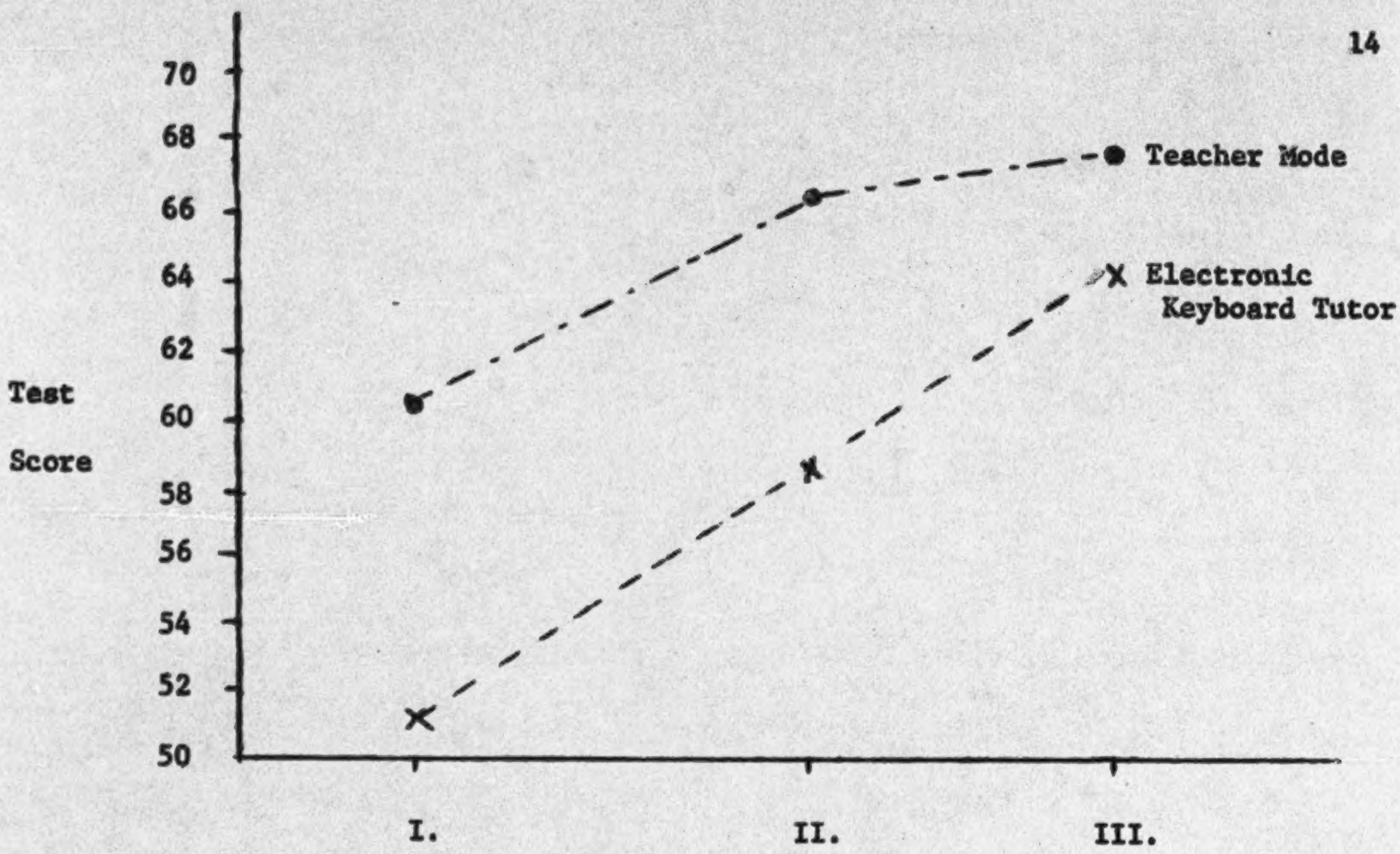

Figure 2. Mean proficiency test scores of subjects having differing entry skills in each instructional mode.

As may be seen in Figure 2, subjects in the conventional teaching situation revealed greater proficiency at all levels after training, although the difference in modes was not statistically significant ($p > .05$). The significant interaction ($p < .01$) resulted apparently from the failure of Level III subjects in the Teacher Mode to exhibit proportionately greater superiority to their counterparts training under the Electronic Keyboard Tutor Mode.

A further ANOVA was made dropping from consideration the 19 subjects who were initially identified as having some piano proficiency (Level III). This analysis is summarized in Table 4 and revealed (1) significant differences in instructional modes ($p < .01$), and (2) significant differences in levels ($p < .05$).

Table 4

Summary Data for ANOVA of Proficiency Scores for Instructional Modes and Proficiency Levels I and II

Source of Variation	d.f.	Sums of Squares	Mean Square	F
MODE	1	1,503.48	1,503.48	14.52**
LEVEL	1	521.00	521.00	5.03*
MODE X LEVEL	1	97.04	97.04	<1
WITHIN	75	7,767.57	103.57	
TOTAL	78	9,889.09		

*$p < .05$
**$p < .01$

These data suggest that for relatively proficient subjects either the Electronic Keyboard Tutor or the conventional teacher Mode provides an adequate instructional vehicle. For the relatively naive subject, however, the conventional mode appears to be superior to the Electronic Keyboard Tutor as it was employed in this study.

The criterion test used in this study had a total possible score of 74 points. The music faculty reviewing the behaviors required on the test in relation to their course objectives arbitrarily defined a score of 60 as being acceptable performance. Of the 102 subjects in the study, 43 demonstrated this level of performance (24 in the Electronic Keyboard Tutor Mode and 19 in the Teacher Mode). The percentage of subjects at the three levels in each mode reaching criterion performance is shown in Table 5.

Table 5

Percent of Subjects Reaching Criterion

	Electronic Keyboard Tutor	Teacher Mode	All Modes
Level I	24	37	32
Level II	55	80	64
Level III	75	71	74
All Levels	38	48	42

Objective #2

"Will students using the Electronic Keyboard Tutor require equal or less practice time to reach a criterion of performance than those taught in the conventional manner?"

An analysis of variance (ANOVA) of practice time was completed and is summarized in Table 6. The ANOVA was again completed with main effects for practice time and instructional mode, both of which were fixed variables.

Table 6

Summary Data for ANOVA of Practice Time in Minutes for Instructional Modes and All Proficiency Levels

Source of Variation	d.f.	Sums of Squares	Mean Squares	F
MODE	1	4,724,925.73	4,724,925.73	105.14**
LEVEL	2	198,434.49	99,217.29	2.21
M x L	2	245,957.64	122,978.82	2.74
WITHIN	92	4,134,332.10	44,938.39	
TOTAL	97	9,303,649.96		

**p < .01

As indicated above, the ANOVA revealed a significant difference in practice time between instructional modes, but not between levels. There was no significant interaction between entry level and instructional mode. Mean practice times (Mode X Level) are shown in Table 7.

Table 7

Mean Practice Time of Entry Levels by Instructional Mode

Instructional Mode	Level I	Level II	Level III	Total
EKT Mode	86	73	55	78.32
Teacher Mode	393	588	313	536.59

Objective #3

"Will student attitudes, as measured by a Thurstone-type scale, indicate a positive effect toward the learning of the skills in question by using the Electronic Keyboard Tutor?"

The Thurstone-type Attitude Toward Instruction Test (see Appendix B) was administered to all subjects who received instruction under the Electronic Keyboard Tutor Mode. Values scores of the test ranged from a scale of 1 (positive) to 11 (negative). The measured attitudes of the total number of subjects ranged from a high of 2.8 to a low of 8.8, with a mean of 5.9. By entry levels the attitudes were as follows: Level 1, 6.1; Level 2, 5.7; and Level 3, 5.8. The attitude of the subjects was decidedly neutral, and could be considered to be less enthusiastic toward the instructional mode than that held by the investigator.

Objective #4

"After working with the Electronic Keyboard Tutor, will teachers indicate a preference for continuing its use or for returning to the conventional instruction?"

Four staff members participated as instructors in the two instructional modes. One member was a victim of terminal illness and was replaced by another member, who, as it developed, was the only member to teach in both instructional modes. This same member declared a preference to continue using the EKT. The other two members, because of class schedule, taught in the EKT Mode only. They declared no preference for either the EKT or the conventional mode. Their reasons are discussed in the next section.

Discussion and Recommendations

A characteristic common to many students in music fundamentals classes is their reluctance to practice the piano outside of class. Under the conventional mode of instruction, this reluctance is often overcome only through concerted effort of the teacher. When students are under no pressure from the teacher to practice regularly, and are free to determine their own practice schedules, the result frequently will be irregular or perhaps even no practice. This reluctance of students to practice was noticed by the investigator in this study and, although no explanation is attempted here, should be kept in mind by the reader when results of this study are considered.

Objective #1 was concerned with the actual teaching effectiveness of the EKT. If it were effective, a student could become proficient at playing scales and chord progressions without requiring a teacher to monitor the practice. The data showed the Teacher Mode to be superior to the EKT at all three entry levels. In addition the mean score for each level under the Teacher Mode was above the arbitrary criterion score. By comparison, the only entry level of the EKT Mode whose mean score reached criterion was Level 3. These results indicate that the EKT, as employed in this study was not as effective a training medium for the non-proficient students as was the Teacher Mode.

The data for Objective #2 revealed that although the subjects of the Teacher Mode were able to perform at criterion level, they did so by practicing a significantly greater amount of time. The mean practice time for all entry levels was decidedly less for the EKT Mode subjects. At Level 3, where both modes' subjects reached criterion, the Teacher Mode subjects practiced approximately six times that of the EKT Mode. The favorable difference for the EKT in practice time was maintained at the other two entry levels, although the criterion scores favored the Teacher Mode. The effect of more practice by the EKT subjects on their performance is a moot point. For various reasons a considerable number of subjects did not practice on the EKT with any enthusiasm.

One reason for the lack of applied practice among the EKT Mode subjects might be traced to the interaction between the subject and the EKT. It is possible that the EKT failed to supply a vital item of information to the subject when it relayed the feedback. In line with this, there is a possibility that the learning pattern of the non-proficient student is uniquely different from that of the somewhat proficient student.

The functions of the EKT were designed to make the feedback relatively painless for the subject. Lights were used to indicate the correctness of the played note and the position of the note within its sequence. In addition, the student was given the freedom to actively "seek out" the correct fingering in the event of an error. Apparently this built-in discovery feature of the EKT had an effect upon some subjects which had not been anticipated. It is possible that the feedback of error only is insufficient for the non-proficient student. The subject might lack sufficient confidence to search and learn by himself. More information, perhaps in the form of prompts, could help him achieve a satisfactory learning experience. This consideration is given some basis by the written opinions which were obtained from EKT Mode, Level 1, subjects following their training. They are quoted here.

"I feel that the EKT is a waste of time for the novice. If I can't figure out what is wrong with my play, I can only sit there and feel ridiculous. The EKT can't talk or tell me what is wrong."

"I spent more time on the EKT just trying to get it to work than I did playing on it."

Other subjects were apparently satisfied with the EKT. It is possible that these subjects possessed the necessary quality to meet the challenge of finding the correct play by themselves. Two other Level 1 subjects are quoted as follows.

"I feel that I learned faster on the EKT than I would have on a regular piano."

"The EKT is able to check my work all of the time. A teacher is not."

With subjects from the same entry level expressing such extreme opinions, it would seem that a review of the instructional mode for possible modification would be in order, particularly in giving more consideration to what subjects need in the way of feedback. As the EKT is now employed, the somewhat proficient student, not the non-proficient student, is the real benefactor. This student apparently has sufficient background which, when he receives knowledge of an error, enables him to make a corrective move without difficulty. Learning seems to take place smoothly and efficiently. Some non-proficient students seem to have this explorative nature and thus benefit in a similar manner. Others may be in need of additional feedback to assure an equally effective learning situation.

The EKT can be modified to supply additional information to the student other than the evaluation of a played note and its relative position within the sequence being practiced. The additional information might be given via numerical indicator plates which would indicate which fingering is necessary to correct for the registered error. Perhaps this added bit of "humanness" to the feedback; that is, the prompting of the student to correct his play, will supply the necessary step to an efficient learning pattern for this type of student. Students who do not require this additional feedback should not be hindered by this modification. Several indications suggest that subjects might "tune out" this extra information and use the EKT in a manner which best fits their own methods of learning.

If the EKT itself is not to be modified, then alteration could be made in the instructional strategy under which it is used. This study revealed that approximately one week of class time was gained by the instructors who used the EKT. With this extra time, instructors could more closely monitor individual student's progress in mastering the assigned keyboard skills. This could be accomplished in several ways. One way could be the spot checking of students, as they practiced on the EKT to assess their progress and help the students in the event of some difficulty. If students are aware that the instructor cares about what they are doing in the way of outside practice, then more practice might be expected. During the study, the EKT Mode subjects did not receive much pressure from the instructors to practice as the collective thinking of the research team felt that the EKT would sell itself.

Another point of consideration in this project is the attitude of the music department staff toward innovative devices (EKT), and their respective influence upon the classes which they teach. Will the staff member feel a threat either from the device itself, i.e., automation, or from being faced with its use? Will the staff member be in agreement with the goals which the device is designed to achieve? These questions are some of the many kinds of questions which are commonly encountered by the initiators of any variation of a well-established method. Music education has had, until recently, relatively few occasions for innovative instructional systems to be tested and implemented. For this reason, attention should be drawn to this condition in the hope that effective methods of implementation can be established. With this end in mind, the following four-step plan for in-service training is suggested:

Step 1. The EKT should be demonstrated for the faculty or staff members. The objective of this demonstration would be to provide evidence to the faculty that the EKT is effective. The staff should see students operating the EKT, in order to get a practical view of its operation.

Step 2. All members of the staff should be given an opportunity to study in depth the techniques being taught and the strategies being used to achieve them. This would permit the staff to relate the objectives of the EKT to their own individual objectives. They could then determine if there is any incompatibility which might hinder effective implementation of the EKT. At this time, the opportunity is open for those who might oppose the EKT to ventilate their feelings by stating the reasons for their opposition. The dissenting members and their statements should be accepted without argument by the total staff and a means found by which these points of variance can be resolved.

Step 3. Once the staff members are convinced of the EKT's effectiveness and of its suitability for their purposes, they should be provided with detailed instruction in its use.

Step 4. Only after the previous steps have been taken should the actual use of the EKT be initiated.

A program as outlined above could have a decided effect upon the music education program in higher education. The modified EKT has demonstrated its ability to achieve considerable economy in teacher time. With the suggested modifications students could be expected to learn the keyboard skills with much less practice time, and with a high degree of proficiency in the absence of a teacher to monitor and tutor their practice.

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Appendix A

Instrument Development

Materials

Mechanical construction of the device utilized pre-manufactured chassis and cabinet materials, a Digital Equipment Corporation (Maynard, Mass.) power supply and card cage with wire wrap terminals.

With exception of the key selector switch, all switches and non-circuitry items such as the elapsed time meter, cable and cable connectors are standard items.

Musical Considerations

The EKT accommodated practice of single octave scales, ascending and descending, in Major, Natural Minor, Harmonic Minor or Melodic Minor Modes. Chords in Major or Harmonic Minor modes can be practiced as triads only or with chord root note in the sequence of I, IV, V^7, I.

Every note key within a scale or a chord progression is represented by consecutively assigned numbers. These numbers do not represent tonal steps, however. This numbering system can be demonstrated with a scale in key of C. The note key is followed by the assigned number. C=1; C# or D^b=2; D=3; D# or E^b=4; E=5; F=6; F# or G^b=7; G# or A^b=9; A=10; A# or B^b=11; and B=12.

Single octave scales are represented with the following enumeration:

	Ascending	Descending
Major	1, 3, 5, 6, 8, 10, 12, 1	1, 12, 10, 8, 6, 5, 3, 1
Nat. Minor	1, 3, 4, 6, 8, 9, 11, 1	1, 11, 9, 8, 6, 4, 3, 1
Har. Minor	1, 3, 4, 6, 8, 9, 12, 1	1, 12, 9, 8, 6, 4, 3, 1
Melodic Minor	1, 3, 4, 6, 8, 10, 12, 1	1, 11, 9, 8, 6, 4, 3, 1

The chording sequence of I, IV, V^7 and I chords is represented by:

Chords	Right Hand	Left Hand	Right Hand
I	1, 5, 8	1	1, 4, 8
IV	1, 6, 10	6	1, 6, 9
V^7	12, 6, 8	8	12, 6, 8
I	1, 5, 8	1	1, 4, 8

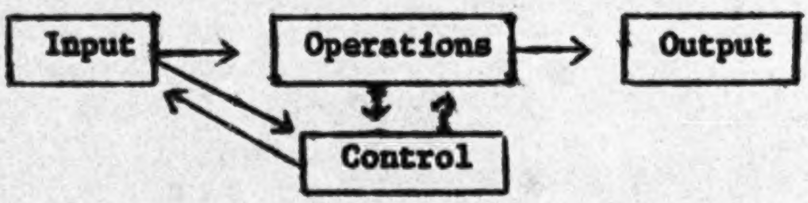
MAJOR

MINOR

These patterns remain constant for every key if the described numbering begins with the first note (name) of the key to be played. This pattern allowed the same circuitry to be used for every musical key without costly duplication. By merely switching the derived inputs so that the number 1 switching output corresponds to the first note of the key, number 2 to the next note and so on, the same set of operations was used for correct/incorrect evaluation in all keys.

System Organization

The four major subdivisions of the EKT are shown below in functional relationship:



A short description of each of these four subdivisions follows:

Input

Input consists of all manipulations made upon the EKT by the student. These include the switching of the various mode and function switches, reset (clear) pedal, as well as the depressing of the piano keys themselves. Before being applied to the Operations and Control circuitry, the piano key switching inputs require modification to insure proper parameter valves. These modifications also take place in the Input subdivision.

Operations

All operations act upon Input data, whether derived directly from Input or via the Control function. These operations are logical in nature and therefore are accomodated by electronic digital logic circuits. It is here that key depression correctness or incorrectness is determined.

Control

Control is threefold: (1) Modes and functions which are determined by the student via Input switches; (2) Proper sequencing via inter-connected flip-flops and their associated decoding circuits, and (3) low level memory (storage) via the operation section of the circuitry.

Output

Output is visual. Lights are used to indicate: (1) Appropriateness of performance by means of correct (proceed) and incorrect (replay) lights. These are actuated at the time of piano key depression; (2) Position within the sequence by means of lights which correspond to each step. For example, if the third positional light is lighted, the student is to perform step three of the sequence. If he does so correctly, that specified light will extinguish and the next (fourth) positional light in the sequence will operate when he releases the piano key(s). If the step is performed incorrectly the position light remains lighted until the correct key or combination is played.

Logic Circuitry

The EKT utilizes two major types of circuitry: (1) The electronic gate, and (2) the bistable multivibrator flip-flop. The function of electric gate circuit is termed conditional, inasmuch as a true or false output state (as measured by potential) is determined by the input state configuration. For example, the

Digital Equipment Corporation R111 gate provides a ground output when all of the inputs are placed at a negative potential. The R121 gate provides a negative output when all of the inputs are at ground potential. A function which requires all of the inputs to be at a particular potential, is called an "AND" function (NAND in these cases, because the output is the opposite or inverse of the inputs). Another function supplied by these circuits is the NOR function. In the case of the R111 gate, whenever one or more of the inputs are at ground potential the output is negative. The DEC R121 gate provides a negative potential whenever one or more of the inputs are at a ground potential. By combining these gate functions the tutoring desired is controlled by the various input-output states.

In the bistable multivibrator flip-flop circuit each input pulse causes the outputs to change state. Therefore pulse #1 applied to the input produces the following effects: Output 1 changes from negative to ground, and Output 2 changes from ground to negative. Pulse #2 applied to the input again will then change the polarity of the outputs. The basic counting circuitry is established when flip-flops are arranged to enable the Output 2 of Flip-flop 1 to furnish input to Flip-flop 2, Output 2 of Flip-flop 2 to furnish input to Flip-flop 3, and Output 2 of Flip-flop 3 to furnish input to Flip-flop 4.

As it is arranged, this counting circuitry retains different output configurations for as many as 16 different counts, including the initial resting state. When the outputs of the four flip-flops are applied to the decoding circuitry, as many as 16 different states are obtained, depending on the count status of the flip-flops. These outputs are an integral part of the determination of correctness and positional information in the EKT.

Input Derivation Logic Circuitry

The input derivation logic circuitry operates in the following manner: Using C as an example; whenever C_1, C_2, or C_3 are depressed (see Figure 3) their outputs go respectively to ground potential. The inputs of the derivation circuits correspondingly will go to ground. If any or all of the inputs of a DEC R111 are grounded, the output goes to a negative potential providing a negative status at point C in Figure 5 and at * in Figure 6. The outcome is a negative potential which occurs at the output whenever any or all of the corresponding input switches are depressed. Whenever C_1 and C_2 or C_2 and C_3 are depressed, ground potentials are applied at the respective inputs and a negative output is obtained at C_1 or *' in Figures 5 and 6. The output at C or * also goes negative when any or all outputs are grounded.

To restate the operation of the input derivation logic circuitry: Whenever one or more piano keys of a kind are depressed, the primary derivation output goes negative. Whenever two adjacent keys of a kind are depressed, the secondary derivation output as well as the primary derivation output goes negative.

Scale Logic - Correct Circuitry

The scale circuitry utilizes seven gates, one being used twice, on the first and eighth scale steps. If a decoded flip-flop state is at 0, or rest position, and the output from switching is negative, the first gate's output goes to ground and this ground potential is applied at point B, Figure 8, of the Chords/Scales Switch and at the input of a R107 inverter. The output of this inverter will be a negative potential and is applied to point A, Figure 8, of the Chords/Scales Switch. In the scales position, this in turn is connected to point F, Figure 10. This point is connected to both the driver of the proceed light, which lights at that time, and the inverter preceding the Schmitt trigger. When the key is released, the Schmitt trigger fires. The flip-flop is triggered one count which provides the next decoding output of T. If the second scale step of 3 is depressed at this time the same described function is performed, the proceed light is on and, upon release of the key, the flip-flop is triggered one count. This function is repeated for the entire scale.

Incorrect Circuitry - (both scales and chords)

Basically the incorrect circuitry asks two questions:

(1) Is a key(s) being played?

(2) Is it played correctly?

Depending on the answers (potentials) to these questions a determination of incorrectness can be made.

The bottom portion of Fig. 9 determines if any of the 12 different notes are being played. If so, the common output line goes to ground and the following R111 gate "NORS" this to a negative potential. This negative potential is applied to one of the inputs of another R111 gate. If the key being played is not correct the line connected to point E of the Chords/Scales Switch will also be at a negative potential. The gate will then perform the NAND function, its output going to ground. This, in turn, is inverted by a R107 inverter and its output, which is now at a negative potential, is applied to the replay lamp driver turning it on, thus indicating an error. The positional light will not advance and will indicate the point at which the error occurred.

Chord Logic - Correct Circuitry

As in the scale logic, if all of the inputs to the number 1-R111 gate are at a negative potential, including the decoded flip-flop input of T_0, T_3, the output line goes to ground and this potential is applied to point D and the input of the R107 inverter. The output of the inverter goes to point C of the Chords/Scales Switch, which, in the chords position, is connected to point F. At point F the same functions occur as in the Scales Mode, thereby turning on the Proceed Lamp and when released, triggering the flip-flop to its next state. The decoding circuitry is modified as shown in the switching diagram to provide four separate states of which, states T_0 and T_3 are applied to the same chord gate.

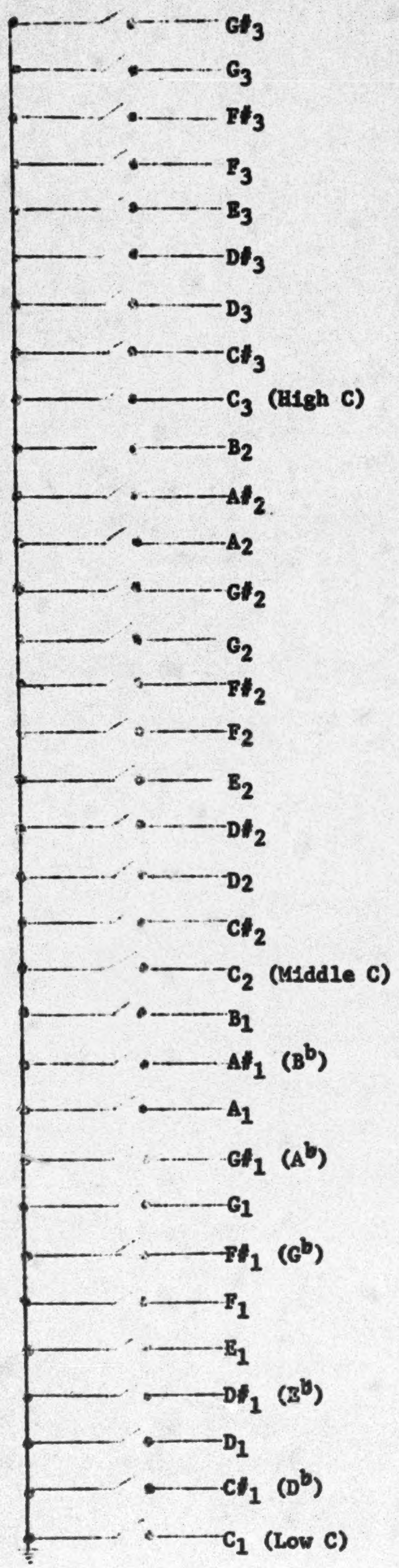
Switching Circuitry

The piano key switches are depicted in figures 3 and 4. Outputs from these switches are carried on a 34 conductor cable (one for each of the 33 keys and one for common ground.) The action of these switches were described in previous sections.

Multiple functions are performed by the Chords/Scales Switch. First, in the Chords position, it disables Flip-flops 3 and 4, thereby limiting the total count capability to track the 4 chord sequence. Second, it modifies the decoding circuits such that, in the Chords position, timing states T and T_3 are coincident. In the scales position, states T_0, T_5, T_7 and T_8 are also coincident states. Third, the Chords/Scales Switch feeds the proper input signals to the readout drivers and to the Schmitt Trigger Inverter.

Key selection utilizes a very large and nonstandard switch of Centralab Corporation manufacture. Its function can be reduced to the simple task of assigning the numbers 1 through 12 electronically to the 12 notes, starting with the name key of the selected key. This assignation was described in reference to the key of C. By selecting another key, this switch places the outputs of the input derivation circuits, classified in terms of piano key names, in correct correspondence with the necessary numbering of the operations circuitry.

Additional switching includes the Major/Minor Switch, the Triads only/ Triads W/Root Switch, and of course the On/Off Switch. The On/Off Switch is not depicted and merely serves to turn power on and off.


$G\#_3$
G_3
$F\#_3$
F_3
E_3
$D\#_3$
D_3
$C\#_3$
C_3 (High C)
B_2
$A\#_2$
A_2
$G\#_2$
G_2
$F\#_2$
F_2
E_2
$D\#_2$
D_2
$C\#_2$
C_2 (Middle C)
B_1
$A\#_1$ (B^b)
A_1
$G\#_1$ (A^b)
G_1
$F\#_1$ (G^b)
F_1
E_1
$D\#_1$ (E^b)
D_1
$C\#_1$ (D^b)
C_1 (Low C)

Piano Key Switch outputs go to input derivation circuitry as indicated.

Whenever a particular key is depressed its switch output goes to ground potential.

As noted the switching only takes place from C below Middle C to G# above C and Middle C.

Figure 3. Piano Key Switching

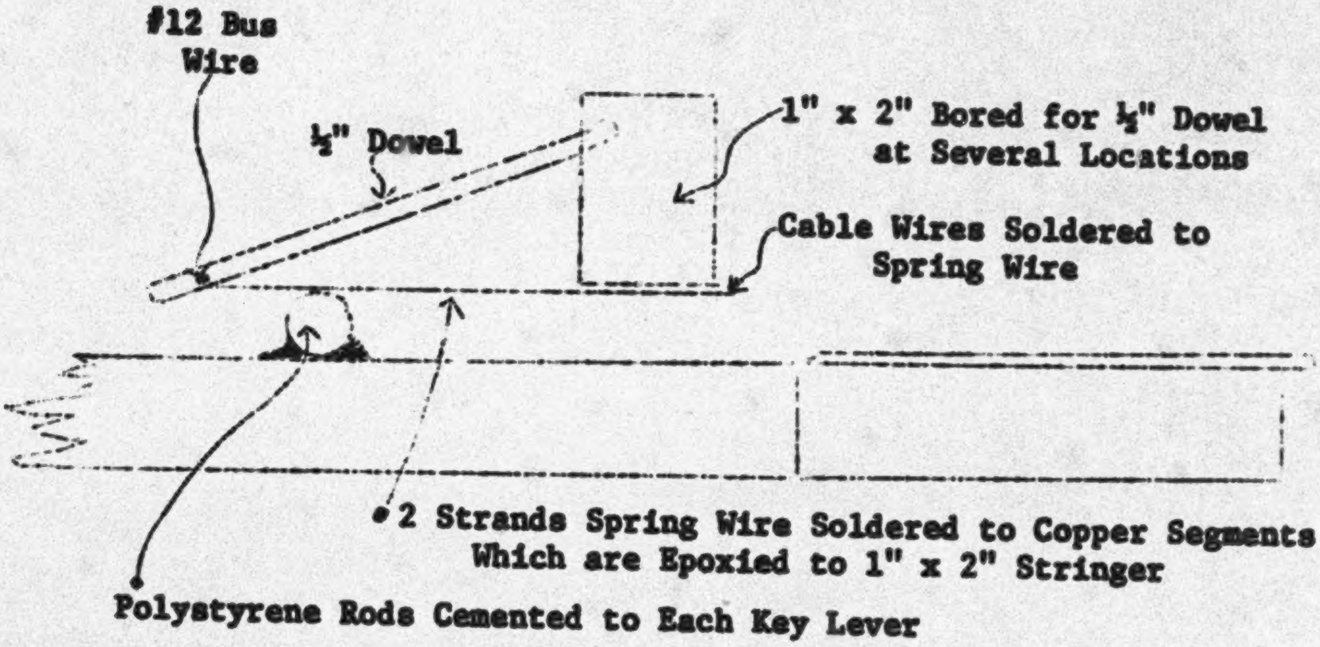

#12 Bus Wire
½" Dowel
1" x 2" Bored for ½" Dowel at Several Locations
Cable Wires Soldered to Spring Wire
2 Strands Spring Wire Soldered to Copper Segments Which are Epoxied to 1" x 2" Stringer
Polystyrene Rods Cemented to Each Key Lever

Figure 4 a. Piano Key Switch Detail: Side View

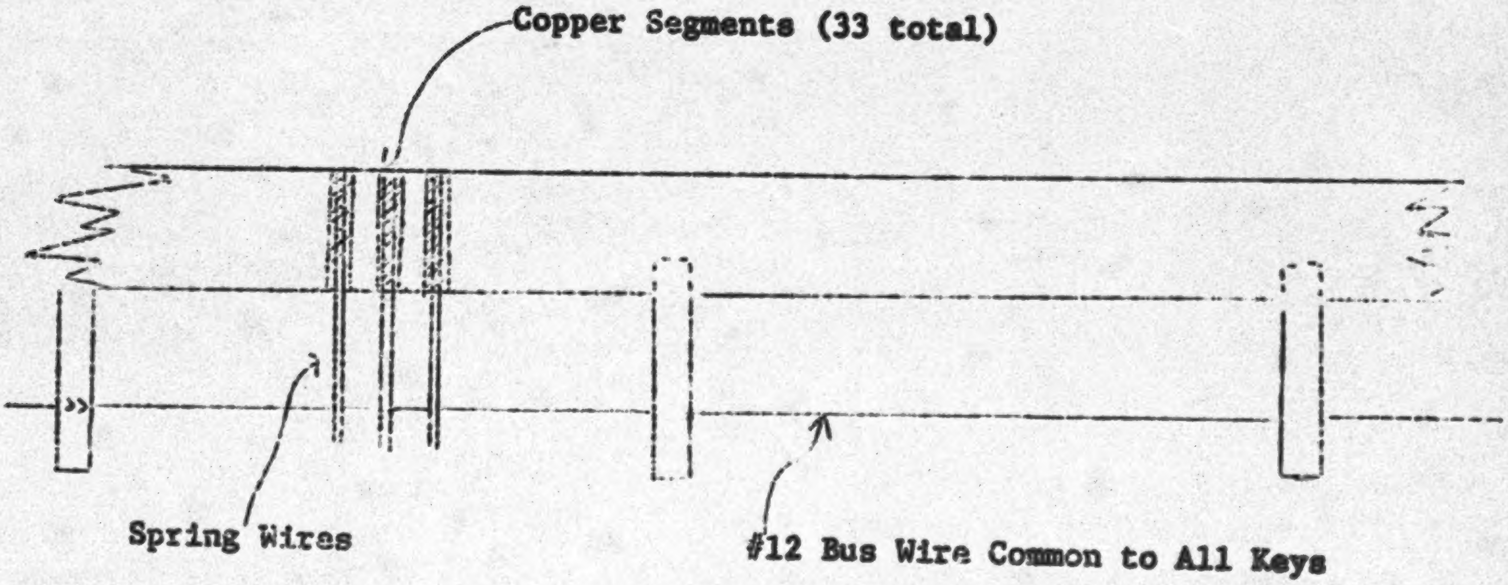

Copper Segments (33 total)
Spring Wires
#12 Bus Wire Common to All Keys

Figure 4 b. Piano Key Switch Detail: Bottom View

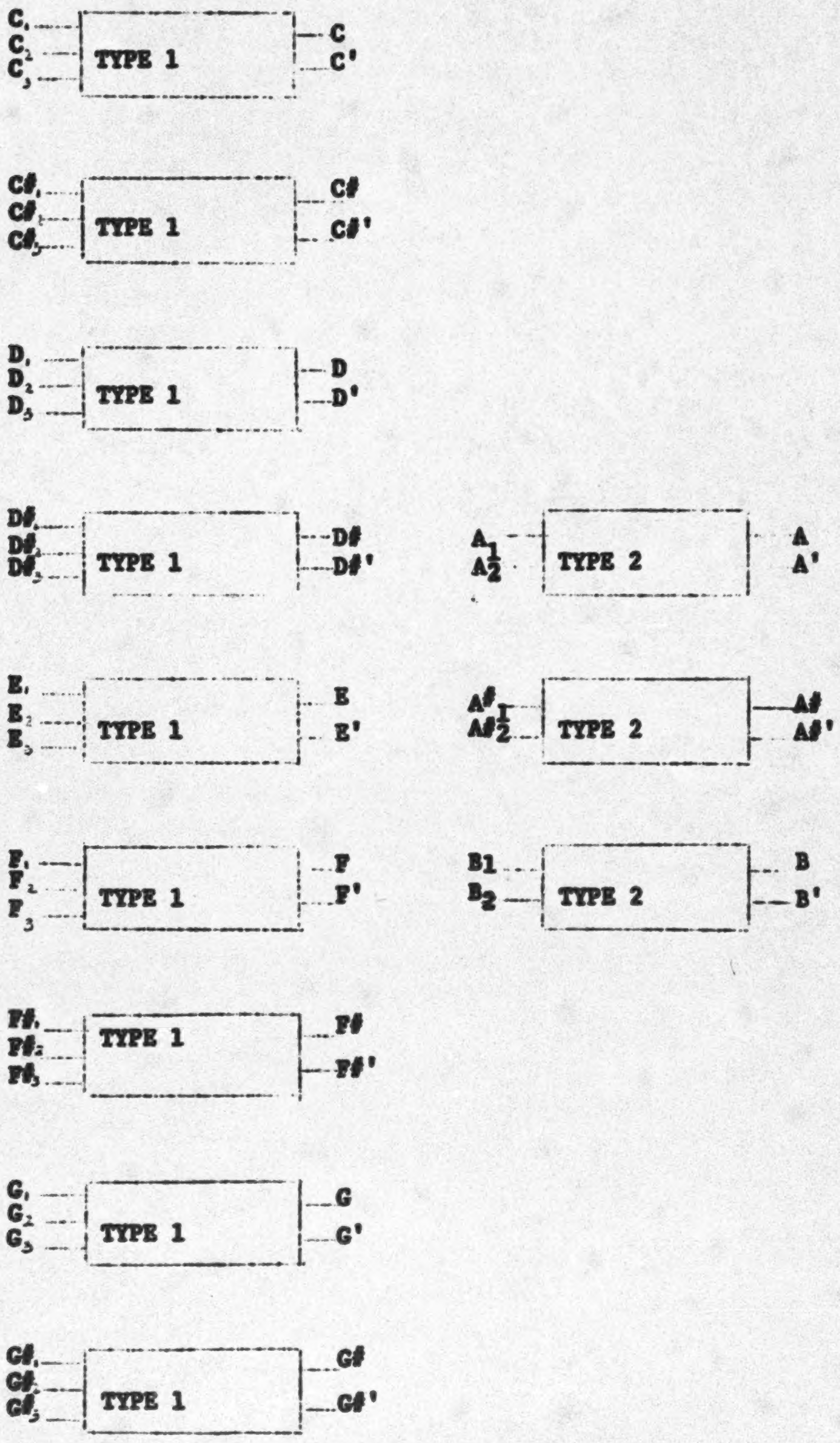

C_1
C_2
C_3
TYPE 1
C
C'
$C\#_1$
$C\#_2$
$C\#_3$
TYPE 1
C#
C#'
D_1
D_2
D_3
TYPE 1
D
D'
$D\#_1$
$D\#_2$
$D\#_3$
TYPE 1
D#
D#'
A_1
A_2
TYPE 2
A
A'
E_1
E_2
E_3
TYPE 1
E
E'
$A\#_1$
$A\#_2$
TYPE 2
A#
A#'
F_1
F_2
F_3
TYPE 1
F
F'
B1
B_2
TYPE 2
B
B'
$F\#_1$
$F\#_2$
$F\#_3$
TYPE 1
F#
F#'
G_1
G_2
G_3
TYPE 1
G
G'
$G\#_1$
$G\#_2$
$G\#_3$
TYPE 1
G#
G#'

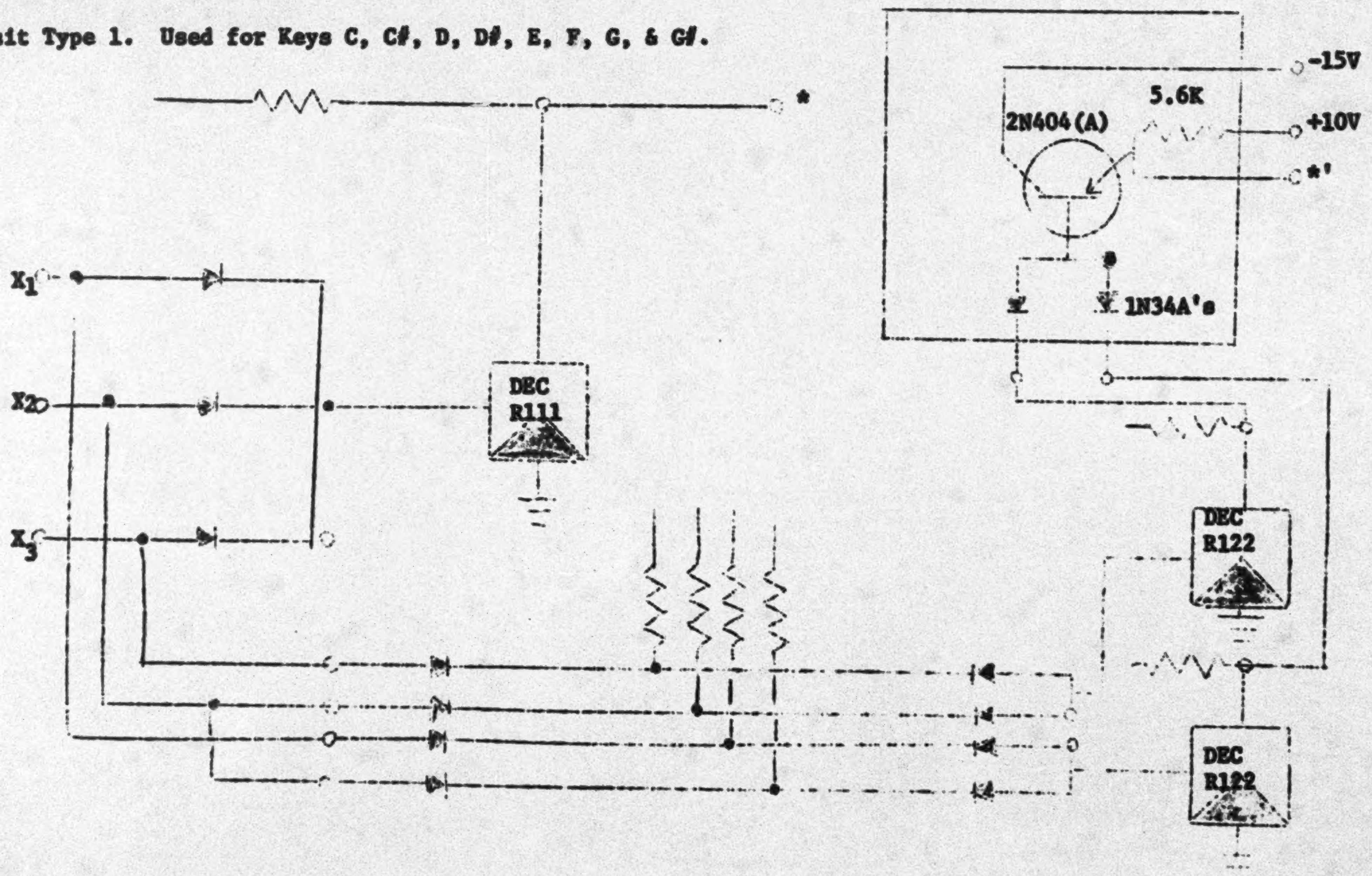
Figure 5. Input Derivation Logic Circuitry

X's refer to outputs of like Piano Key Switches

* refers to derived output

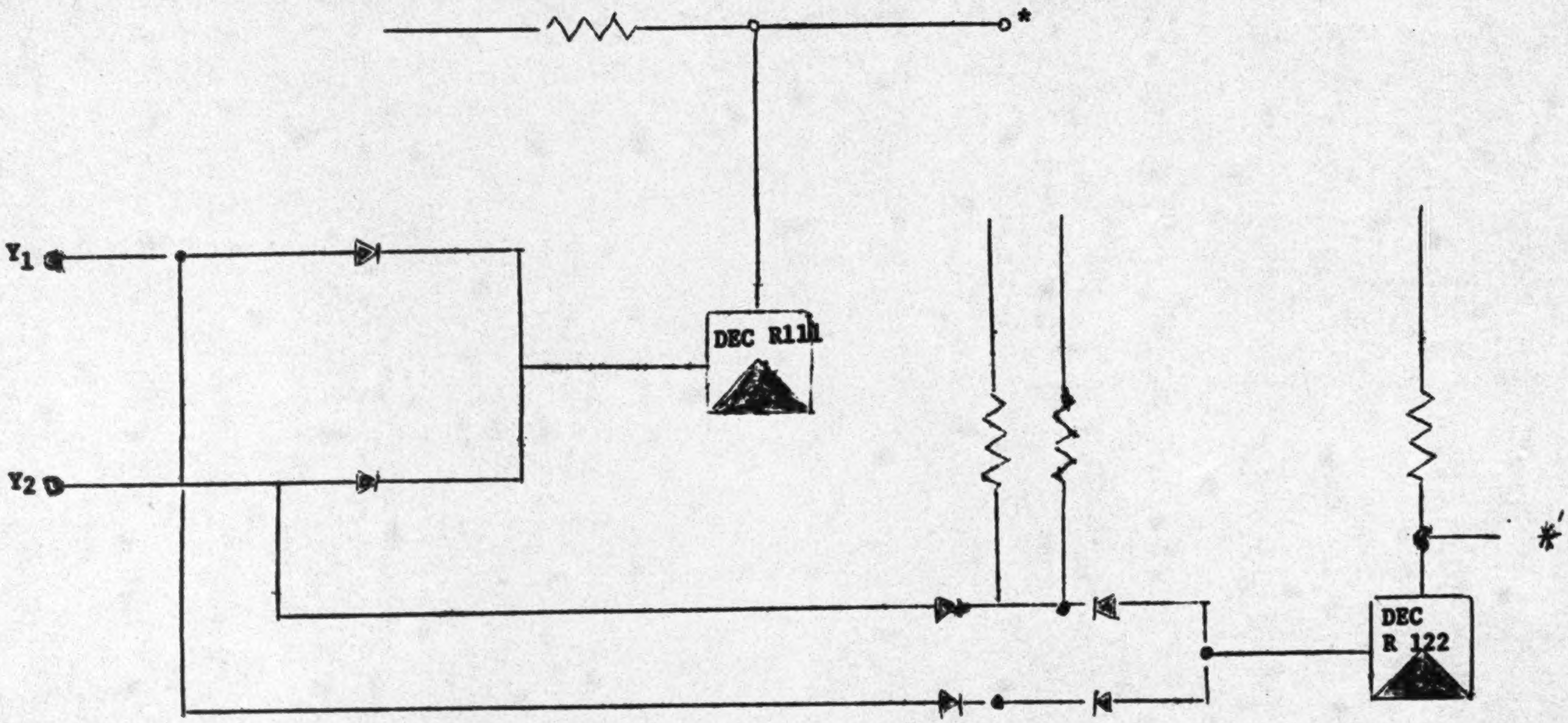
*' refers to secondary derived output

Basic Circuit Type 1. Used for Keys C, C#, D, D#, E, F, G, & G#.



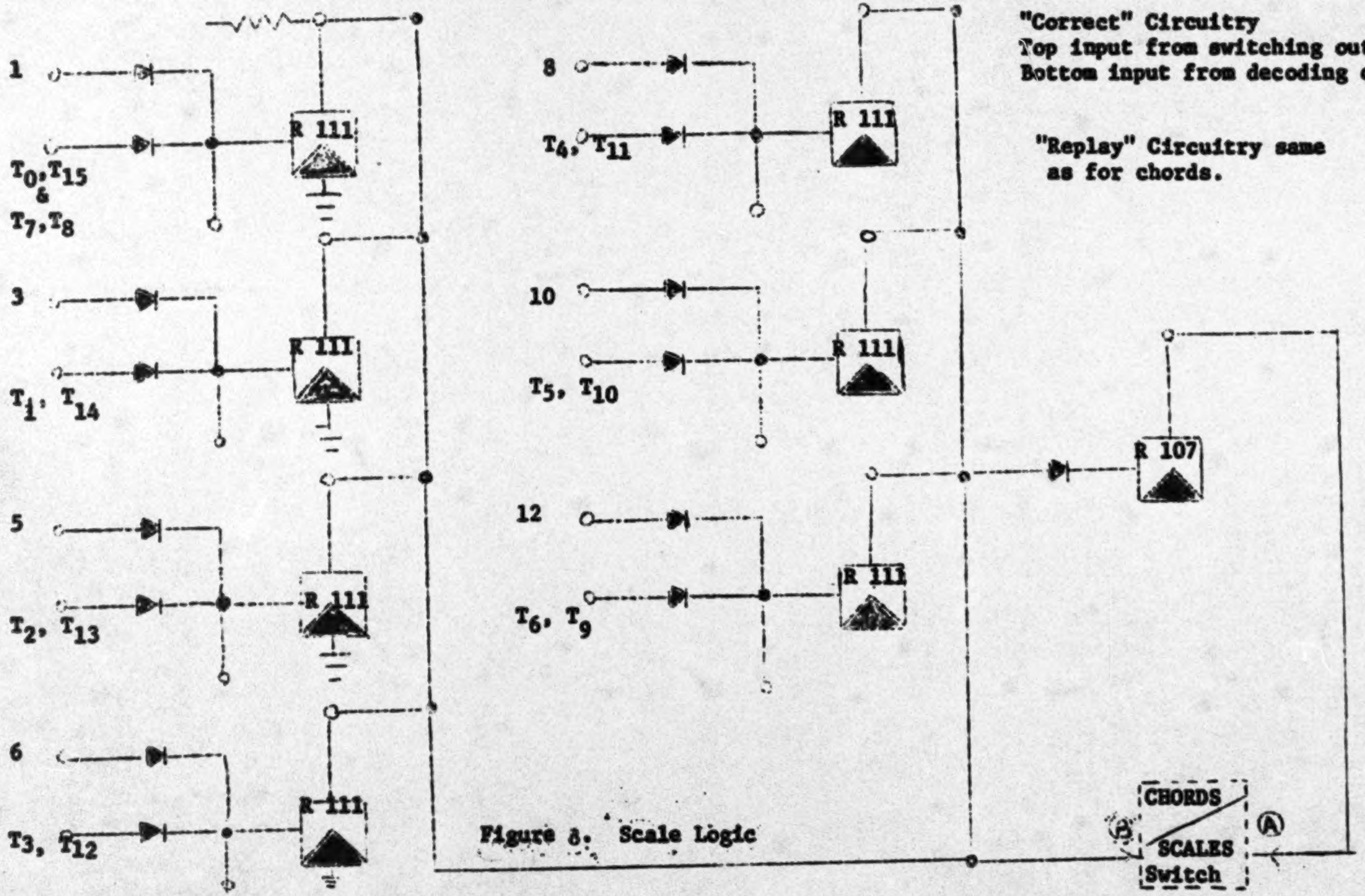
*
-15V
5.6K
2N404(A)
+10V
*'
1N34A's
X_1
X_2
X_3
DEC
R111
DEC
R122
DEC
R122

Figure 6. Input Derivation Logic


*
Y1
Y2
DEC R111
DEC
R 122
*'

Y's refer to outputs of like Piano Key Switches
* refers to derived output
*' refers to secondary derived output
Basic Circuit Type 2. Used for Keys A, A#, & B.

Figure 7. Input Derivation Logic


1
T_0, T_{15} & T_7, T_8
3
T_1, T_{14}
5
T_2, T_{13}
6
T_3, T_{12}
8
T_4, T_{11}
10
T_5, T_{10}
12
T_6, T_9
R 111
R 111
R 111
R 111
R 111
R 111
R 111
R 107
CHORDS
SCALES
Switch
Ⓐ
Ⓑ

"Correct" Circuitry
Top input from switching outputs
Bottom input from decoding outputs

"Replay" Circuitry same
as for chords.

Figure 8. Scale Logic

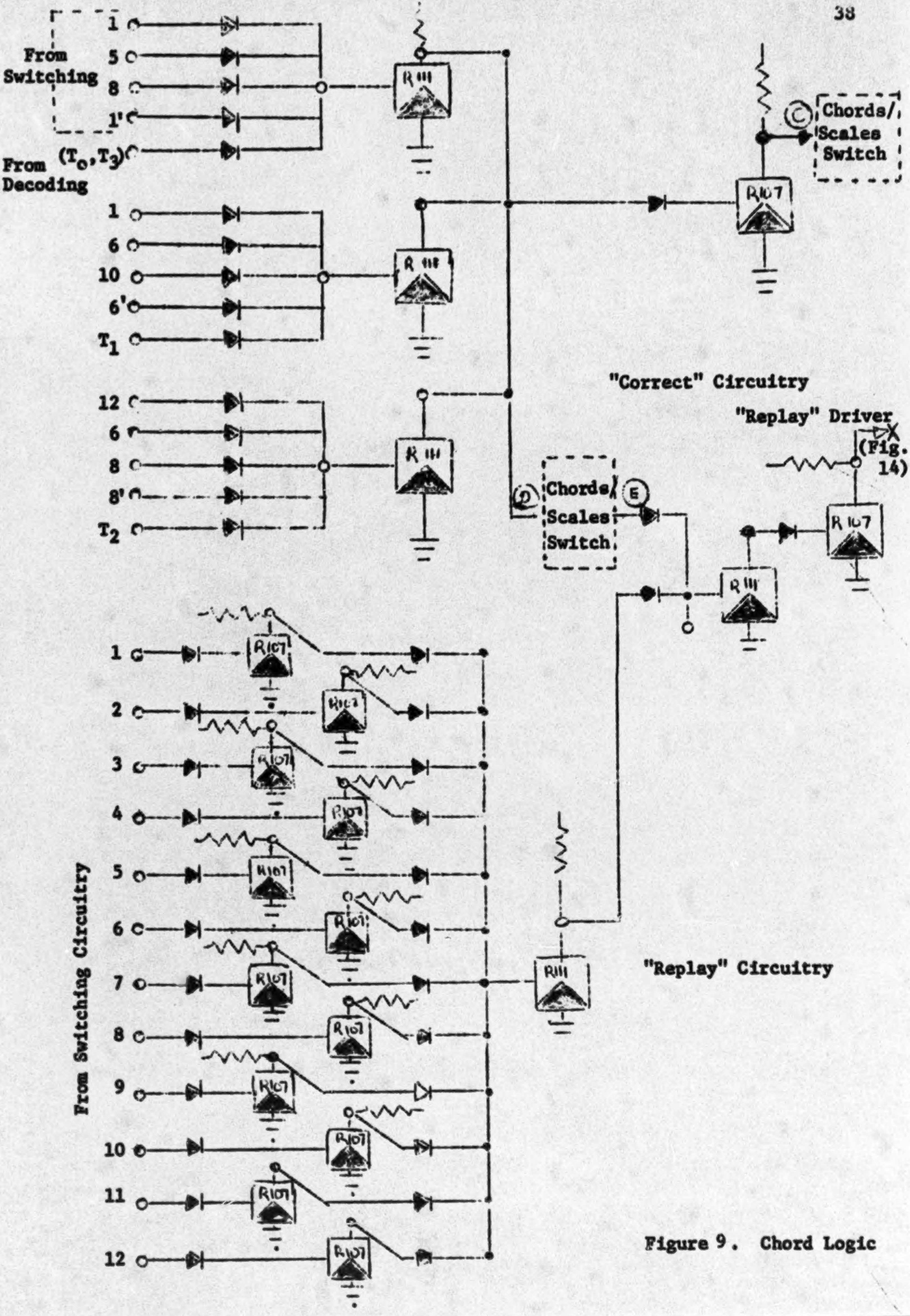
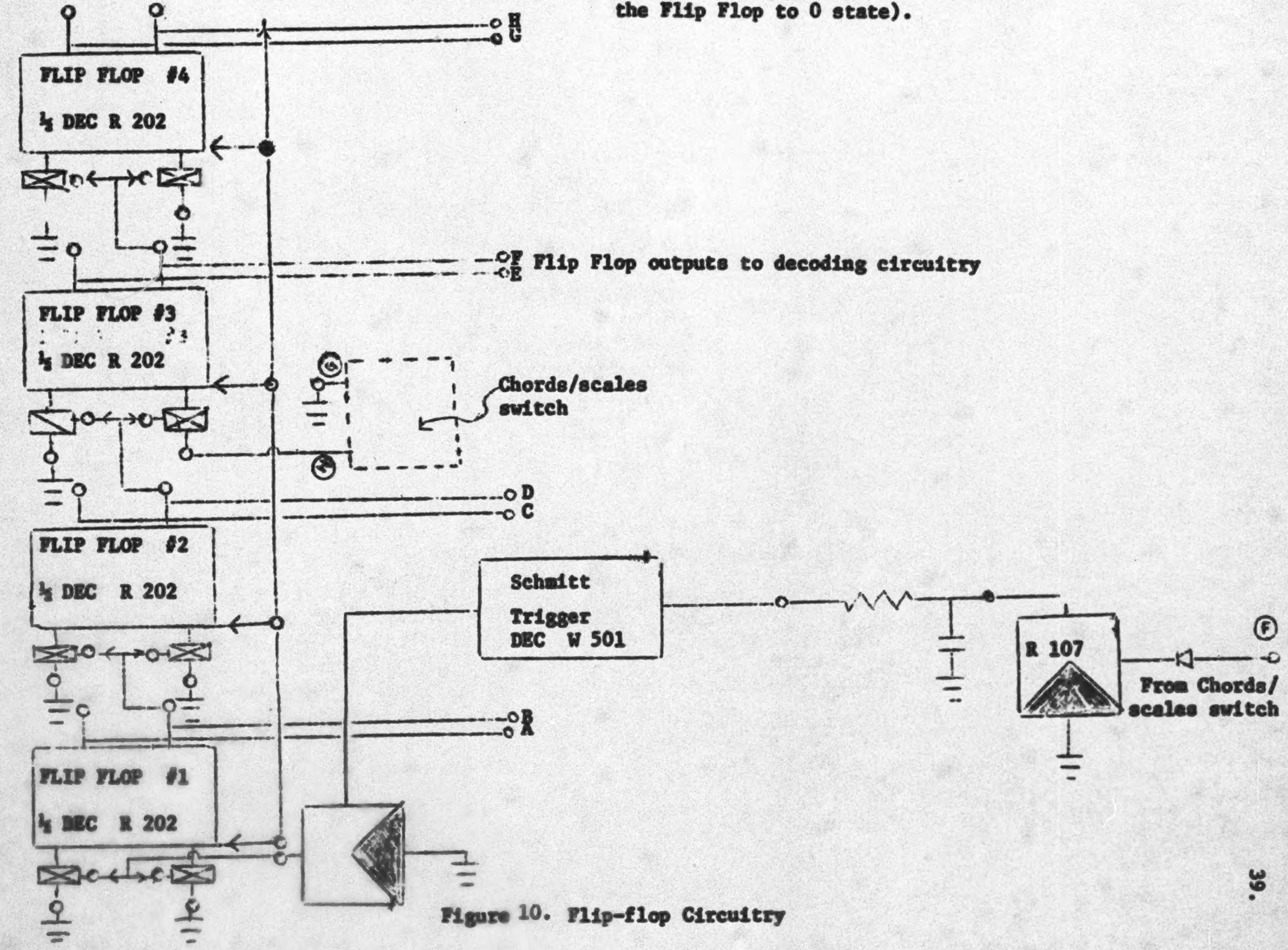

From Switching
1
5
8
1'
From Decoding
(T_0, T_3)
1
6
10
6'
T_1
12
6
8
8'
T_2
R111
R111
R111
Chords/ Scales Switch
C
R107
"Correct" Circuitry
"Replay" Driver
(Fig. 14)
D
Chords/ Scales Switch
E
R111
R107
From Switching Circuitry
1
2
3
4
5
6
7
8
9
10
11
12
R107
R111
"Replay" Circuitry

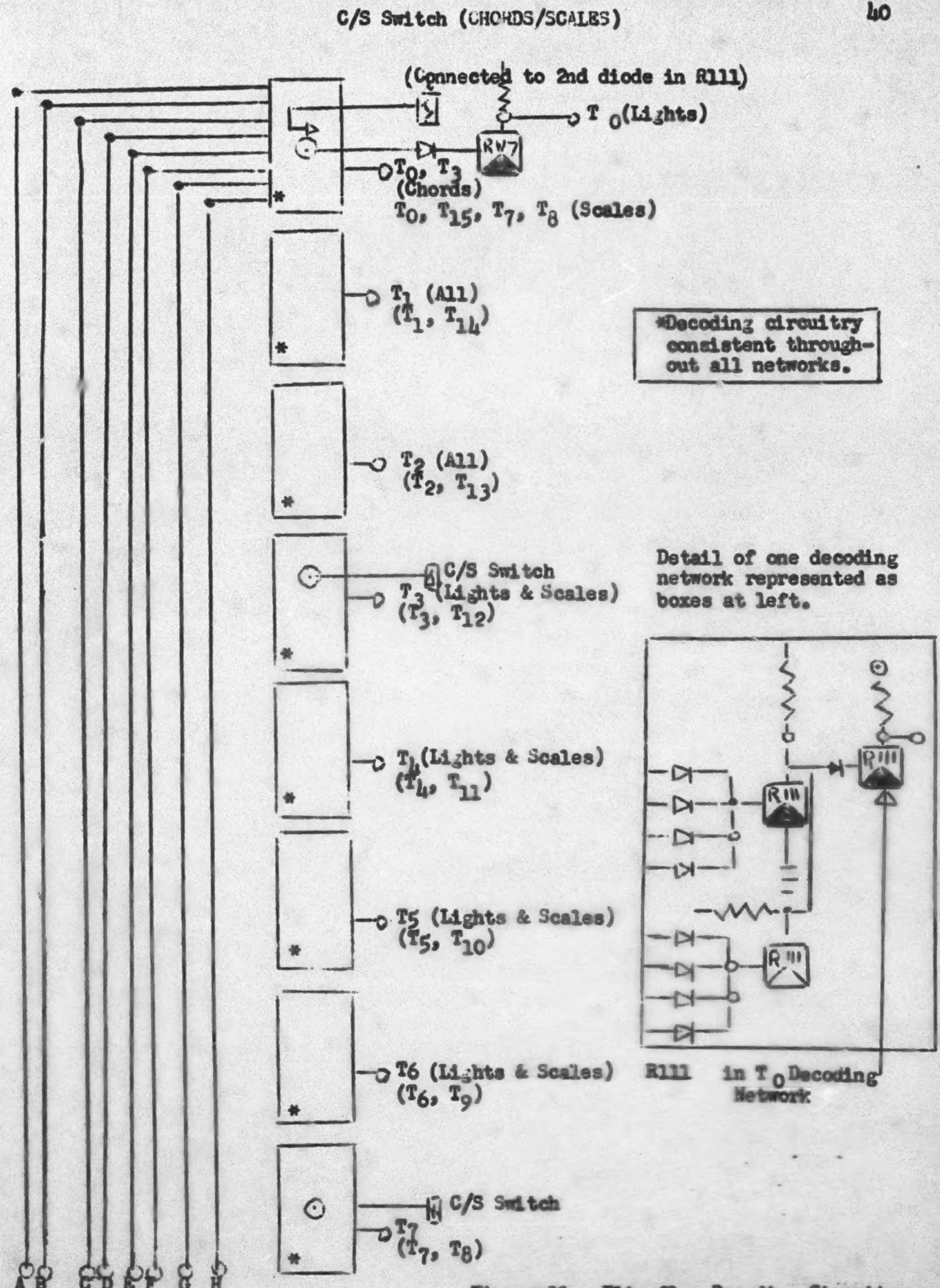
Figure 9. Chord Logic

To reset switch (connecting this point to a negative potential, reset the Flip Flop to 0 state).


H
G
FLIP FLOP #4
½ DEC R 202
F
E
FLIP FLOP #3
½ DEC R 202
Chords/scales switch
D
C
FLIP FLOP #2
½ DEC R 202
Schmitt
Trigger
DEC W 501
R 107
Ⓕ
From Chords/ scales switch
B
A
FLIP FLOP #1
½ DEC R 202

Flip Flop outputs to decoding circuitry

Figure 10. Flip-flop Circuitry


C/S Switch (CHORDS/SCALES)
(Connected to 2nd diode in R111)
T 0(Lights)
RN7
T0, T3 (Chords)
T0, T15, T7, T8 (Scales)
T1 (All) (T1, T14)
T2 (All) (T2, T13)
C/S Switch
T3 (Lights & Scales) (T3, T12)
T4 (Lights & Scales) (T4, T11)
T5 (Lights & Scales) (T5, T10)
T6 (Lights & Scales) (T6, T9)
C/S Switch
T7 (T7, T8)
R111
R111 in T 0 Decoding Network
A B C D E F G H
Flip-flop Outputs

*Decoding circuitry consistent throughout all networks.

Detail of one decoding network represented as boxes at left.

Figure 11. Flip-flop Decoding Circuitry

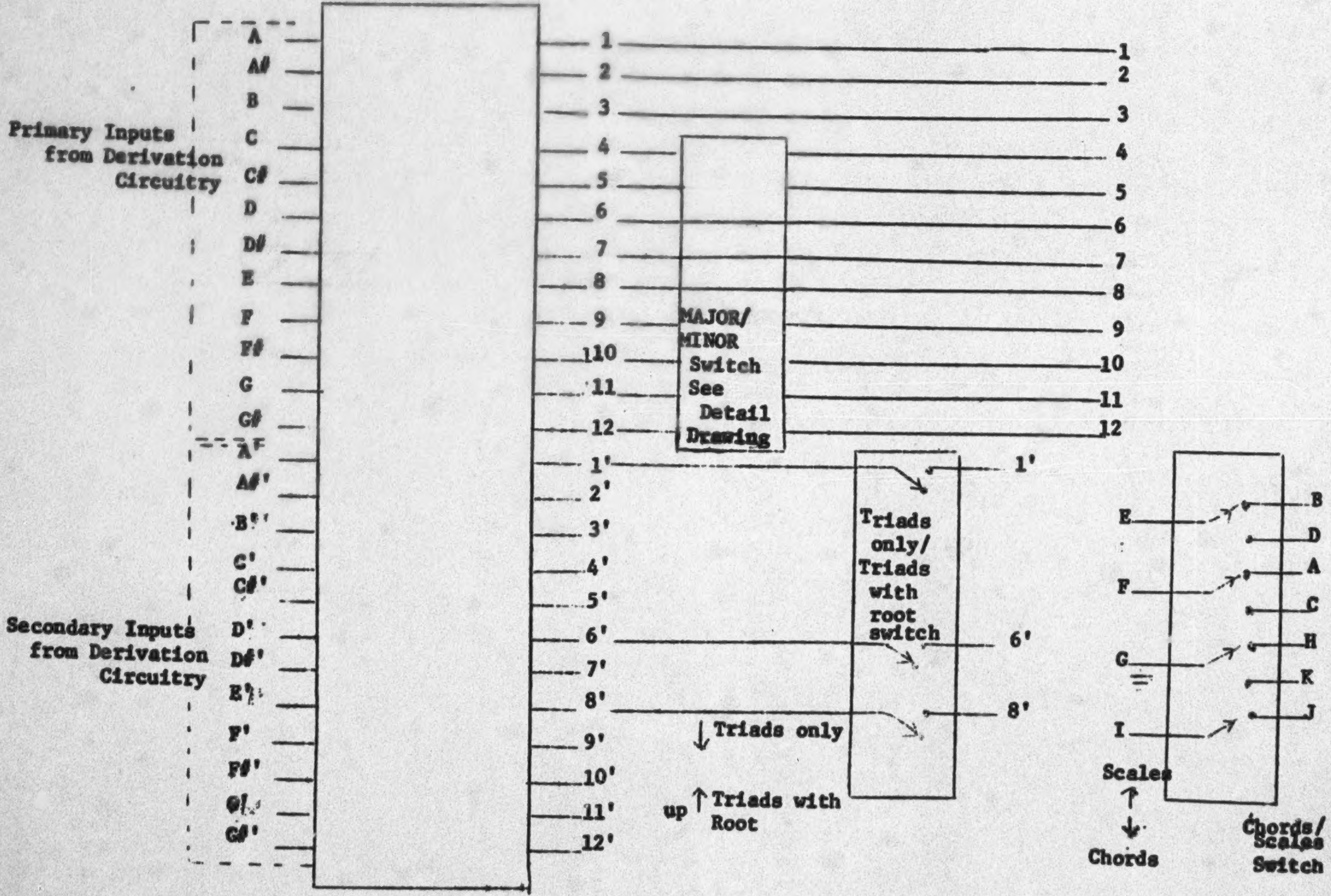

Primary Inputs from Derivation Circuitry
A
A#
B
C
C#
D
D#
E
F
F#
G
G#
Secondary Inputs from Derivation Circuitry
A'
A#'
B'
C'
C#'
D'
D#'
E'
F'
F#'
G'
G#'
1
2
3
4
5
6
7
8
9
10
11
12
1'
2'
3'
4'
5'
6'
7'
8'
9'
10'
11'
12'
MAJOR/ MINOR Switch See Detail Drawing
Triads only/ Triads with root switch
↓ Triads only
up ↑ Triads with Root
E
F
G
I
B
D
A
C
H
K
J
Scales
Chords
Chords/ Scales Switch

Figure 12. Switching Circuitry

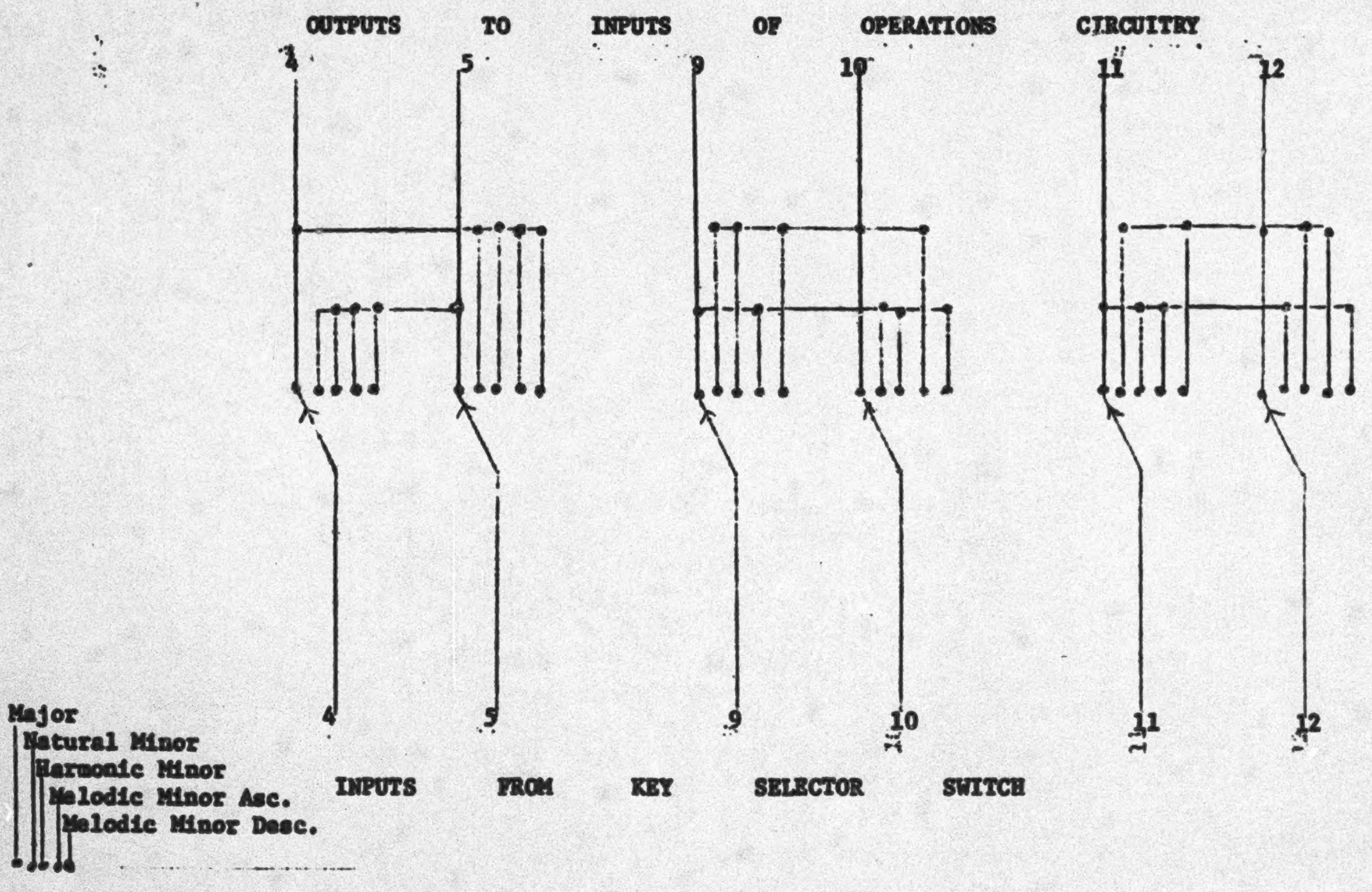

OUTPUTS TO INPUTS OF OPERATIONS CIRCUITRY
4
5
9
10
11
12
4
5
9
10
11
12
INPUTS FROM KEY SELECTOR SWITCH
Major
Natural Minor
Harmonic Minor
Melodic Minor Asc.
Melodic Minor Desc.

Figure 13. Major/Minor Switch Detail

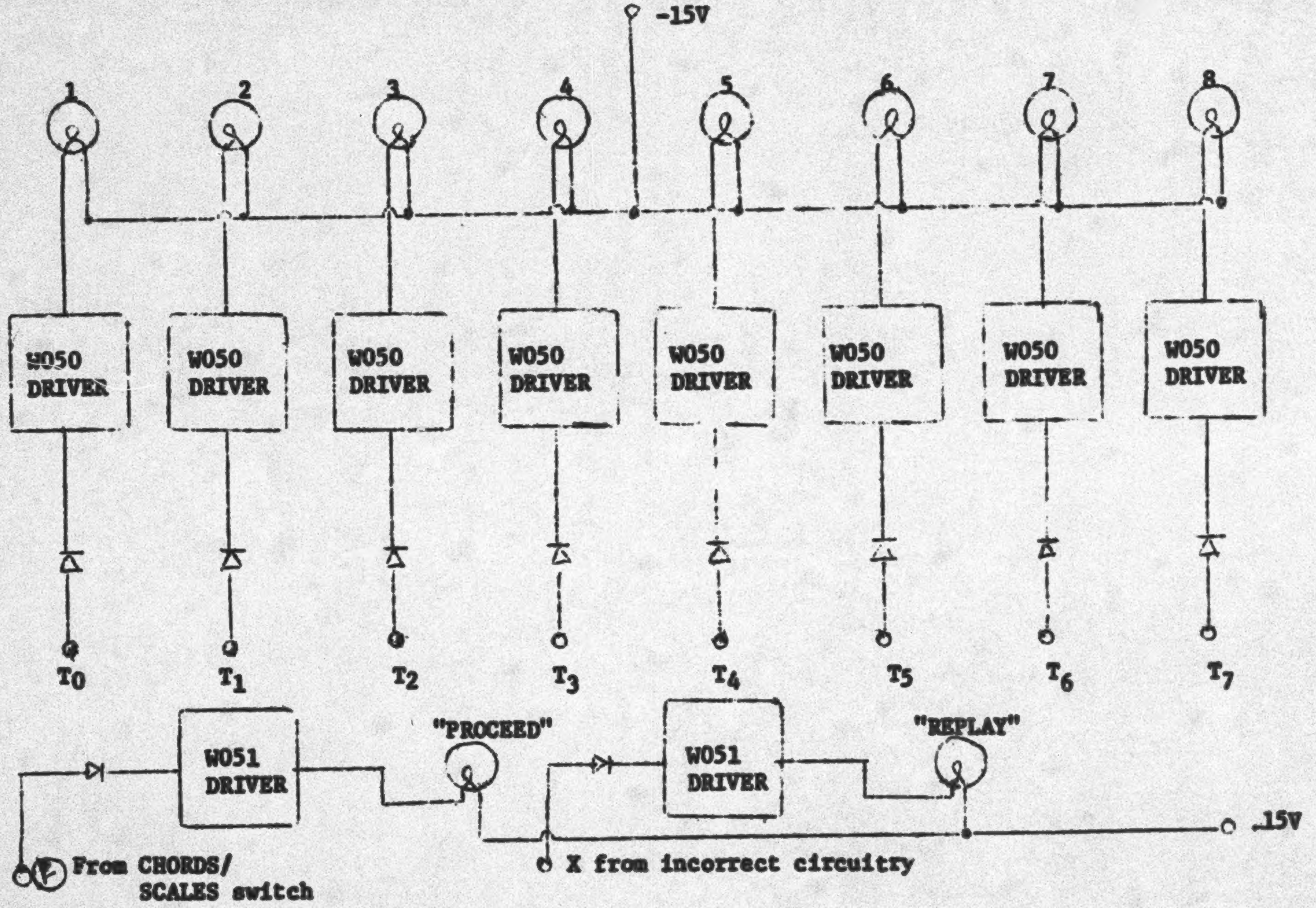

-15V
1
2
3
4
5
6
7
8
W050 DRIVER
W050 DRIVER
W050 DRIVER
W050 DRIVER
W050 DRIVER
W050 DRIVER
W050 DRIVER
W050 DRIVER
T_0
T_1
T_2
T_3
T_4
T_5
T_6
T_7
W051 DRIVER
"PROCEED"
W051 DRIVER
"REPLAY"
15V
F From CHORDS/ SCALES switch
X from incorrect circuitry

Figure 14. Output Indicator Configuration

APPENDIX B

Criterion Performance Test Page 1 Rated by ________ Subject No. ________

Scales: ______Major ______Harm. Minor Date ____________ Total Score ________

Ascend.

Key	A♭	A	B♭	B	C^1	D	E	F	G
Accuracy (✓ missed note)									
1									
2									
3									
4									
5									
6									
7									
8									
(Sub-score 8 points Max/ key)									

____

8									
7									
6									
5									
4									
3									
2									
1									
(Sub-score 8 points Max/key)									

____

Tempo (mm.)									
0 - 60									
60 - 86									
86 - 100									
100 - over									
(Sub-score 4 points Max/key)									

____

Regularity (Ascending) (1 worst 5 best)									
1									
2									
3									
4									
5									
(Sub-score 5 points Max/key)									

____

SCALE SCORE ________

Appendix B Cont.

Criterion Performance Test Page 2.

Chord Progressions: ____________Major ________Harm. Minor

KEY	A♭	A	B♭	B	C^1	D	E	F	G	C^2	C^3
Accuracy (✓ missed note)											
I											
IV											
V7											
I											
Sub-total (4 pts. Max/key)											

____

(Tempo (mm.))											
0 - 60											
60 - 86											
86 - 100											
100 - over											
Sub-total (4 pts. Max/key)											

____

Regularity (1 worst 5 best)											
1											
2											
3											
4											
5											
Sub-total (5 pts. Max/key)											

____

CHORD PROGRESSIONS SCORE ________

SCALES SCORE ________

TOTAL SCORE ________

APPENDIX C

Name ______________________________

Electronic Piano Keyboard Project
Student Evaluation

This institution is involved in a research project which features student use of electronic self-instruction on a piano keyboard. One aspect of the overall program concerns students' reactions to this kind of training.

You are asked to identify yourself on this sheet so that a more complete statistical comparison can be made. The data from this response sheet will be combined with the other data on a program of computer analysis. All replies will be kept confidential and will have no bearing on your grade for the course.

INSTRUCTIONS

Listed below are 33 statements of attitude toward self-instruction via the electronic device, i.e., the tutor. Read each statement and decide whether or not you agree with it. If the statement represents your attitude, circle the number of that statement.

Please select no more than five (5) statements.

1. The tutor is a waste of time.
2. The tutor does not teach anything.
3. I would recommend that other students avoid using the tutor.
4. Using the tutor is boring.
5. The tutor is too cumbersome to be of any value.
6. The tutor adds very little to my knowledge.
7. Those flashing lights make my jumpy.
8. The tutor distracts me from learning the fingerings.
9. The tutor doesn't do as good a job as a human instructor.
10. Using the tutor makes me nervous.
11. It is hard for me to adjust to using the tutor.
12. I know when I make a mistake, so I don't need the tutor to flash its light at me.
13. Perhaps others might use the tutor and benefit more than I did.
14. The tutor was too impersonal.
15. I wouldn't recommend that other people use the tutor any more than I would recommend that they practice on the regular piano.
16. It makes little difference to me whether or not I use the tutor.
17. The tutor is useful to me only for a certain length of time.
18. I am not sure how much the tutor taught me.

18. I am not sure how much the tutor taught me.

19. The tutor does not waste my time.

20. The tutor helped me to learn the correct fingerings.

21. The tutor will help people who are tone deaf.

22. While using the tutor I never felt embarrassed when I made a mistake.

23. The tutor teaches me in a way that I will remember.

24. The tutor helped me to develop "an ear for the correct tone of the notes."

25. I was amazed that the tutor could teach me so well.

26. The tutor speeds up my practice and makes it more efficient.

27. Were I to be given a choice, I would gladly use the tutor again.

28. My music course was made more enjoyable because I used the tutor.

29. The tutor gives me help which I could not get from a human teacher.

30. Using the tutor is exciting.

31. I believe everyone should have an opportunity to use the tutor.

32. The tutor teaches the material better than a human teacher.

33. Training on the tutor is a good deal-fast and effective.